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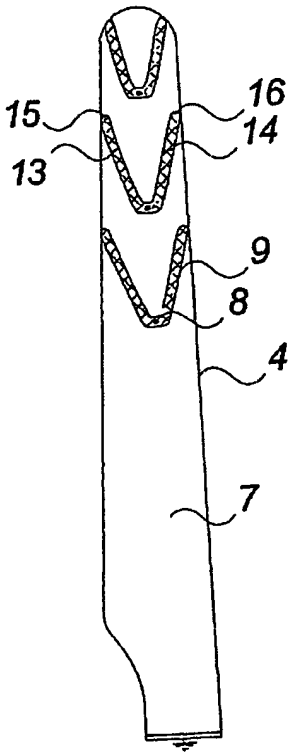
(54) Title: LIGHTNING PROTECTION SYSTEM FOR, E.G., A WIND TURBINE, WIND TURBINE BLADE HAVING A LIGHTNING PROTECTION SYSTEM, METHOD OF CREATING A LIGHTNING PROTECTION SYSTEM AND USE THEREOF



(57) Abstract: The invention relates to a lightning protection system for, e.g., a wind turbine, the system comprising one or more internal conducting means (7). The invention also relates to one or more external lightning conducting means (9) mounted on the surface or in immediate proximity of the surface of said turbine and connection means by means of which said internal (7) and external (9) lightning conducting means are connected. The invention further relates to a method of creating a lightning protection system for, e.g. a wind turbine, a wind turbine blade and use thereof.

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Published:
— *with international search report*

Lightning protection system for, e.g., a wind turbine, wind turbine blade having a lightning protection system, method of creating a lightning protection system and use thereof.

The present invention relates to a lightning protection system for a construction, a method of creating a lightning protection system and use thereof.

A number of different lightning protection systems for protection of constructions are known within the art and have been known for several centuries. In particular, a type of construction which needs to be protected is wind turbines and their blades. Wind turbines are usually erected in open spaces or in the recent years at sea where they form the highest point and often attract lightning. The blades of the wind turbine reach the highest position and are therefore the usual place of impact for lightning.

In the past, the fact that blades were often made of a non-conductive material such as glass fibre lead to the belief that lightning was not a problem. However, such blades are often covered by a thin layer of dust, salt or pollution and together with moisture, the risk of conducting a current is real and results in several unprotected blades being damaged or destroyed by lightning.

The issue of establishing lightning protection for wind turbine blades has generated several different solutions.

A first solution is the use of a tape comprising a conductive layer with the tape being connected to a ground plane. The tape is positioned on the surface at the front edge of the blade from the tip of the blade and downwards. When lightning strikes the blade, the impact will usually be on the tape due to the path to the ground plane.

An example of this state-of-the-art is disclosed in EP-A 1011182.

The surface-mounted tape generates a number of problems, such as inductive problems, which has lead to the development of lightning protection being built into the blade. The protection involves a metal wire with a ground plane connection

which extends through the blade longitudinally and penetrates the surface close to the tip of the blade. The point of penetration attracts lightning which is then conducted to ground without damaging the blade.

The internal lightning protection has proved to offer reliable protection for blades of a limited length in the nearness of the point of penetration. With the development of ever longer blades, the system cannot protect the blade in its entire length. Especially, the internal system described above cannot protect a long blade with efficiency.

An example of this state-of-the-art is disclosed in WO-A 9607825.

The object of the invention is to create a lightning protection system which may protect all types and sizes of constructions in danger of being struck by lightning in a reliable manner.

The invention

In accordance with the invention, claim 1 states a lightning protection system for a construction comprising one or more internal lightning conducting means in said construction where said internal lightning conducting means includes a connection to a ground plane, one or more external lightning conducting means having certain a surface mounted on the surface or in immediate proximity of the surface of said construction, and connection means by means of which said internal and external lightning conducting means are connected.

Initially, the lightning protection system offers efficient interception of lightning by the external lightning conducting means and subsequently efficient conduction of the lightning by the internal lightning conducting means. Especially the possibility of extending the surface of the external lightning protection means in combination with an internal lightning conduction is advantageous in achieving an efficient interception and down conduction of the lightning.

The number of connection means may also be minimized due to the size of the external lightning conductors where the number of connection means is a significant price factor in construction of e.g. a wind turbine blade as well as a factor in the mechanical characteristics of the construction.

Further by establishing an easier path with the lightning protection system may indirectly control any electrostatic field distribution (low frequency fields) where the distribution of electrostatic fields in a construction usually controls the place of impact for a lightning.

Any tribo electric charging of wind turbine blades or aeroplane wings by the dry air sweeping over the blades or wings may also efficiently be avoided or conducted to a ground plane.

Even further the lightning protection system shields the construction against damage caused by any electric field such as electrostatic fields and the tribo electric charging. Hereby a further protection of the different electric circuits in the construction is obtained during a stroke of lightning as well as under normal use. Examples of different electric circuits may e.g. be sensors and heating elements in and on wind turbine blades.

It is important to point out that the term "external" should be understood as a lightning conductor which may be hit by lightning directly by being mounted on the surface of the construction or in the near proximity of the surface. The mounting may preferably be established by means of an adhesive layer between the external lightning conduction means and the surface. The skilled person within the art will understand that other types of fastening means may be used e.g. bolts, screws or rivets.

The term "having a surface" should be understood as the surface of an external lightning conductor with a certain size large enough to establish an active protection of the construction.

The connection means between the internal and external lightning conducting means may be a wire, a rod or form of bolt connected to the internal lightning conducting means by means of welding, soldering or a simple mechanical connection.

Further the connection means may be a distance of a non-conductive or poor-conductive material between the internal and external lightning conducting means. The distance needs to be of such a length that the lightning still chooses it as the path to the internal lightning conducting means.

It should be emphasized that the invention may be used in many arrangements even though the invention is primarily described in relation to the blades of a wind turbine. One further arrangement may be wings of an aeroplane or the like.

When, as stated in claim 2, said internal lightning conducting means is a wire or rod, and preferably with a diameter of 8 to 20 millimetres, it is possible to construct a conductor which can conduct the current of lightning without melting or generating too much heat afflicting damage to the construction.

When, as stated in claim 3, said internal lightning conducting means is positioned in the longitudinal centre line of the construction, a preferred embodiment of the invention has been obtained.

It shall be emphasized that the internal lightning conducting means may be positioned anywhere inside the construction.

When, as stated in claim 4, said external lightning conducting means are made of a current conducting material such as a metal band, and preferably a copper band, it is possible to direct lightning to a ground plane in an advantageous way. The use of a

metal band is particularly advantageous since the thinness of the band allows positioning of the band on a construction surface without changing the characteristics of the construction significantly.

It should be empasized that the direction of lightning to a ground plane may be conducted in the current conducting material or guided in the near proximity of the current conducting material as an ionisation of the air.

When, as stated in claim 5, said current conducting material is a tape or a fine-meshed net or another thin layer of conducting material, a preferred embodiment of the invention has been obtained.

Especially, with use of the current conducting material an aerodynamic blade may be established. The current conducting material is also easy to mount and position.

When, as stated in claim 6, said current conducting material has one end connected to said connection means and the other end extending freely, a preferred embodiment of the invention has been obtained.

By extending one end freely e.g. toward the edge of a wind turbine blade the amount of current conducting material being used may be minimized. The current conducting material may also connect in both ends to the internal lightning conducting means or to current conducting material extending from another connection means.

When, as stated in claim 7, the free end of said current conducting material extends in direction towards the tip of the construction such as the tip of a wind turbine blade, it is possible to direct the current to a ground plane without causing parallel conductor paths. Parallel conductor paths may be established if the direction is away from the tip and may cause damage to the material between the parallel conductors that typically is the blade material.

When, as stated in claim 8, the extension of said external lightning conducting means is curved, an advantageous current path has been established. The use of an extension with an angular part is possible but may result in a powerful reaction against the angular part when lightning is conducted. The electrodynamic action may be so powerful that the extension is loosened from the surface on which it is positioned.

When, as stated in claim 9, said external lightning conducting means has a length of 0.1 to 5 meters, and preferably less than 2.5 meters, it is possible to establish a preferred embodiment of the invention. The length is important in order to achieve an efficient lightning protection system since too long external lightning conducting means may cause electrical break down discharges e.g. between the tip of the external lightning conducting means and the internal lightning conducting means through the construction. Electrical break down discharges may also be established between the external lightning conducting means and other current conducting means if the external lightning conduction means is too long. The other current conducting means may e.g. be moisture or dirt on the inside or outside of the construction, wires or other components in the construction.

When, as stated in claim 10, said external lightning conducting means has a width of 0.01 to 0.5 meters, and preferably 0.05 to 0.2 meters, a preferred embodiment of the invention has been obtained.

When, as stated in claim 11, said current conducting material is mounted as a layer on the surface of the construction, it is possible to achieve an efficient lightning protection system where the construction will not be damaged by lightning. Further, the layer will maintain the aerodynamic characteristics of the construction to a large extent.

When, as stated in claim 12, said current conducting material is mounted in a groove in the construction before the groove is sealed, the aerodynamic characteristics of the construction will be maintained and damage by lightning to the construction will only be limited. The sealing of the groove will not keep lightning from striking the

current conducting material but the sealing will puncture or even vanish when lightning strikes.

It shall be empasized that the mounting also may be combination of the stated in claim 11 and 12.

When, as stated in claim 13, a number of external lightning conducting means extends from said connection means, and preferably two external lightning conducting means from one of said connection means, a preferred embodiment of the invention has been obtained.

When, as stated in claim 14, the connection between said external lightning conducting means and said connection means is at least one proximity coupling, it is possible to allow a small insulating gab in the coupling means between the external lightning conducting means and the connection means and the internal conducting means, as the lack of electric contact is without effect since the lightning voltage is usually at least 20 kV which means that lightning will pass the proximity coupling anyway. The proximity coupling is especially advantageous since it is easy to establish by e.g. gluing the external lightning conducting means onto the top of the connection means. An electric coupling may be established by using a conductive adhesive or by welding or soldering. Further, an electric coupling may be established by mechanical means or connections.

When, as stated in claim 15, said external lightning conducting means is placed on each side of the construction, a preferred embodiment of the invention has been obtained. Since the position of lightning impact is difficult to predict by nature, the placing of external lightning conducting means on each side is advantageous.

When, as stated in claim 16, said external lightning conducting means is placed in the top half of the construction, sufficient and price-efficient protection has been achieved since lightning rarely strikes in the lower half of the construction.

When, as stated in claim 17, a substantially parallel part of said external lightning conducting means in relation to said internal lightning conducting means is displaced away from the internal lightning conducting means, it is possible to increase the distance between the external lightning conducting means and the internal lightning conducting means. With the increase in distance, the possibility of an electrical break down discharge through the construction to be protected is reduced.

The lightning protection system may be established on a construction such as a blade or a wing during the manufacturing. However, the external lightning conduction means may also be supplementary mounted on exiting blades or wings. The right length of the external lightning conducting means may be adapted to the given blade or wing e.g. by the use of scissors or a knife.

Drawings

The invention will be described in detail in the following with reference to the drawings of which

Fig. 1 shows a state-of-the-art wind turbine,

Fig. 2 shows a blade of a rotor used in the wind turbine of fig. 1,

Fig. 3 shows a blade with a number of penetrations to an internal lightning conducting means,

Fig. 4 shows a preferred embodiment of a blade according to the invention,

Fig. 5 shows the blade with a different pattern,

Fig. 6 shows a cross-view of a blade according to the invention seen from tip of the blade, and

Fig. 7 shows a cross-view of the blade seen from the side.

Detailed description

Fig. 1 shows a standard wind turbine 1 including a tower 2, a nacelle 3 and a rotor with a number of blades 4. The wind turbine further has a lightning conductor in the shape of a connection 6 to a ground plane 5 and the connection extends from the ground plane through the tower and nacelle to the centre of the rotor. From the centre of the rotor the connection extends through the interior of the blades to the tip of the blades. The internal connection is an internal lightning down conductor e.g. in shape of a wire.

Fig. 2 shows a section of the rotor and one blade 4 in full length. At the tip of the blade, the penetration point 8 of an internal lightning protection system is shown. Further is the internal lightning protection system shown together with the ground plane and the connection connecting the two.

Fig. 3 shows a blade with internal lightning conducting means. There are three penetration points 8 on the surface of the blade 4 and the penetration points are the heads of the connection means 12. The penetration points are present on each side of the blade and may be positioned in a centre line of the blade. Each of the connection means has a connection to the internal lightning conducting means 7.

Fig. 4 shows a lightning air-terminal in the shape of an external lightning conducting means 9 positioned on the surface of a blade 4 in a preferred pattern according to the invention. The pattern includes three sets of curved extensions 13, 14 from a penetration point 8 of the connection means 12 which has a connection to the internal lightning conducting means 7. Each of the curved extensions sets 13, 14 is established by means of two extension arms which extend up against the tip of the blade on each side of the centre line of the blade. The free ends 15, 16 of the extensions 13, 14 will usually be at the edges of the blade 4.

The extensions from a penetration point 8 may be any given number and the pattern may also be non-symmetrical e.g. only extensions toward the front edge of the construction.

The extensions are preferably made of copper tape with a length less than 2.5 metres and a width of 0.05 to 0.20 metres e.g. 0.15 metres. The tape includes an adhesive layer that ensures a durable connection to the surface of the construction and may include a protection layer on top of the copper.

In a preferred method the external lightning protection means in the shape of current conducting material are supplementary mounted on the construction however it may as well be mounted at the fabrication of the construction.

The current conducting material may also be mounted in a groove in the construction. A layer of e.g. paint will afterward be used to seal the groove. The groove will not keep lightning from striking the current conducting material but the sealing will puncture or even vanish when lightning strikes.

Fig. 5 shows another pattern of the external lightning protection means 9, 10 where the current conducting material extends from the penetration points 8. The current conducting material is shown on a part of the blade as two extensions 13, 14 extending toward the edges of the blade 4.

Further, the fig. 5 shows that the current conducting material on the blade tip may be three extensions 10 extending toward the edge of the tip.

An extension may also connect with other extensions e.g. a connection establishing contact along the tip edge of the blade tip between the three extensions 10.

Fig. 6 shows a cross-view of a blade 4 according to the invention seen from the tip of the blade. The internal lightning conducting means 7 is preferably a wire or rod of a current conductive material such as copper with a diameter of 8 to 20 millimetres e.g.

12 millimetres. The wire or rod may be placed in the longitudinal centre line of the blade and has connection means 12 establishing a connection to the surface of the blade or near the surface and further to an external lightning conducting means 9.

Fig. 7 shows a further cross-view of the blade 4 seen from the side. The figure illustrates a section of the blade with the wire or rod of the internal lightning conducting means 7. The wire or rod extends longitudinally through the blade from the tip of the blade or substantially from the tip to the centre of the rotor or to the attachment of the blades on the rotor. The connection means 12 extend perpendicularly to the internal lightning conducting means 7 and ends in this embodiment just above the surface of the blade 4 where the external lightning conducting means 9 is positioned on top of the connection means 12. The connection means may be a wire, a rod or form of bolt connected to the internal lightning conducting means 7 by means of welding, soldering or a simple mechanical connection.

List

1. Wind turbine
2. Tower
3. Nacelle
4. Blade of a rotor
5. Ground plane
6. Ground plane connection
7. Internal lightning conducting means
8. Point of penetration
9. Pattern of external lightning conducting means
10. Pattern of external lightning conducting means on a blade tip
11. Blade tip
12. Connection means
13. First extension
14. Second extension
15. Free end of first extension
16. Free end of second extension

Patent Claims

1. Lightning protection system for a construction such as a wind turbine (1) with blade (4) comprising

one or more internal lightning conducting means (7) where said internal lightning conducting means includes a connection (6) to a ground plane (5),

one or more external lightning conducting means (9, 10) having a surface mounted on the surface or in immediate proximity of the surface of said construction, and

connection means (12) by means of which said internal (7) and external lightning conducting means (9, 10) are connected.

2. Lightning protection system according to claim 1 wherein said internal lightning conducting means (12) is a wire or rod preferably with a diameter of 8 to 20 millimetres.

3. Lightning protection system according to claim 1 or 2 wherein said internal lightning conducting means (7) is positioned in the longitudinal centre line of the construction.

4. Lightning protection system according to any of the claims 1 to 3 wherein said external lightning conducting means (9, 10) is made of a current conducting material such as a metal band and preferably a copper band.

5. Lightning protection system according to any of the claims 1 to 4 wherein said current conducting material is part of a tape or a fine-meshed net or another thin layer of conducting material.

6. Lightning protection system according to any of the claims 1 to 5 wherein said current conducting material has one end connected to said connection means (12) and the other end (15, 16) extending freely.

7. Lightning protection system according to any of the claims 1 to 6 wherein the free end (15, 16) of said current conducting material extends in the direction towards the tip (11) of the construction such as the tip of a wind turbine blade.

8. Lightning protection system according to any of the claims 1 to 7 wherein the extension (13, 14) of said external lightning conducting means (9, 10) is curved.

9. Lightning protection system according to any of the claims 1 to 8 wherein said external lightning conducting means (9, 10) has a length of 0.1 to 5 meters, and preferably less than 2.5 meters.

10. Lightning protection system according to any of the claims 1 to 9 wherein said external lightning conducting means (9, 10) has a width of 0.01 to 0.5 meters, and preferably 0.05 to 0.2 meters.

11. Lightning protection system according to any of the claims 1 to 10 wherein said current conducting material is mounted as a layer on the surface of the construction.

12. Lightning protection system according to any of the claims 1 to 11 wherein said current conducting material is mounted in a groove in the construction before the groove is sealed.

13. Lightning protection system according to any of the claims 1 to 12 wherein a number of said external lightning conducting means (9, 10) extends from said connection means (12) and preferably two external lightning conducting means (9, 10) from one of said connection means (12).

14. Lightning protection system according to any of the claims 1 to 13 wherein the connection between said external lightning conducting means (9, 10) and said connection means (12) is at least one proximity coupling.

15. Lightning protection system according to any of the claims 1 to 14 wherein said external lightning conducting means (9, 10) is placed on each side of the construction.

16. Lightning protection system according to any of the claims 1 to 15 wherein said external lightning conducting means (9, 10) is placed in the top half of the construction.

17. Lightning protection system according to any of the claims 1 to 16 wherein a substantially parallel part (13, 14) of said external lightning conducting means (9, 10) in relation to said internal lightning conducting means (7) is displaced away from the internal lightning conducting means (7).

18. Wind turbine blade (4) having a lightning protection system, said blade comprising

one or more internal lightning conducting means (7) where said internal lightning conducting means includes a connection (6) to a ground plane (5),

one or more external lightning conducting means (9, 10) having a surface mounted on the surface or in immediate proximity of the surface of said blade (4), and

connection means (12) by means of which said internal and external lightning conducting means are connected.

19. Method of creating a lightning protection system for a construction having one or more internal lightning conducting means and connection means, said method comprising the steps of

placing a current conducting material on the surface of said construction,

adapting said current conducting material to a desired length,

establishing attachment of said current conducting material to said surface with the aid of fastening means attaching the current conducting material with the surface, and

establishing a direct or indirect connection between said current conducting material and said connection means.

20. Method according to claim 19 wherein said fastening means is an adhesive layer.

21. Use of a lightning protection system according to any of the claims 1 to 17 and/or method according to any of the claims 19 and 20 in connection with blades of wind turbines.

22. Use of a lightning protection system according to any of the claims 1 to 17 and/or method according to any of the claims 19 and 20 in connection with wings of aeroplanes.

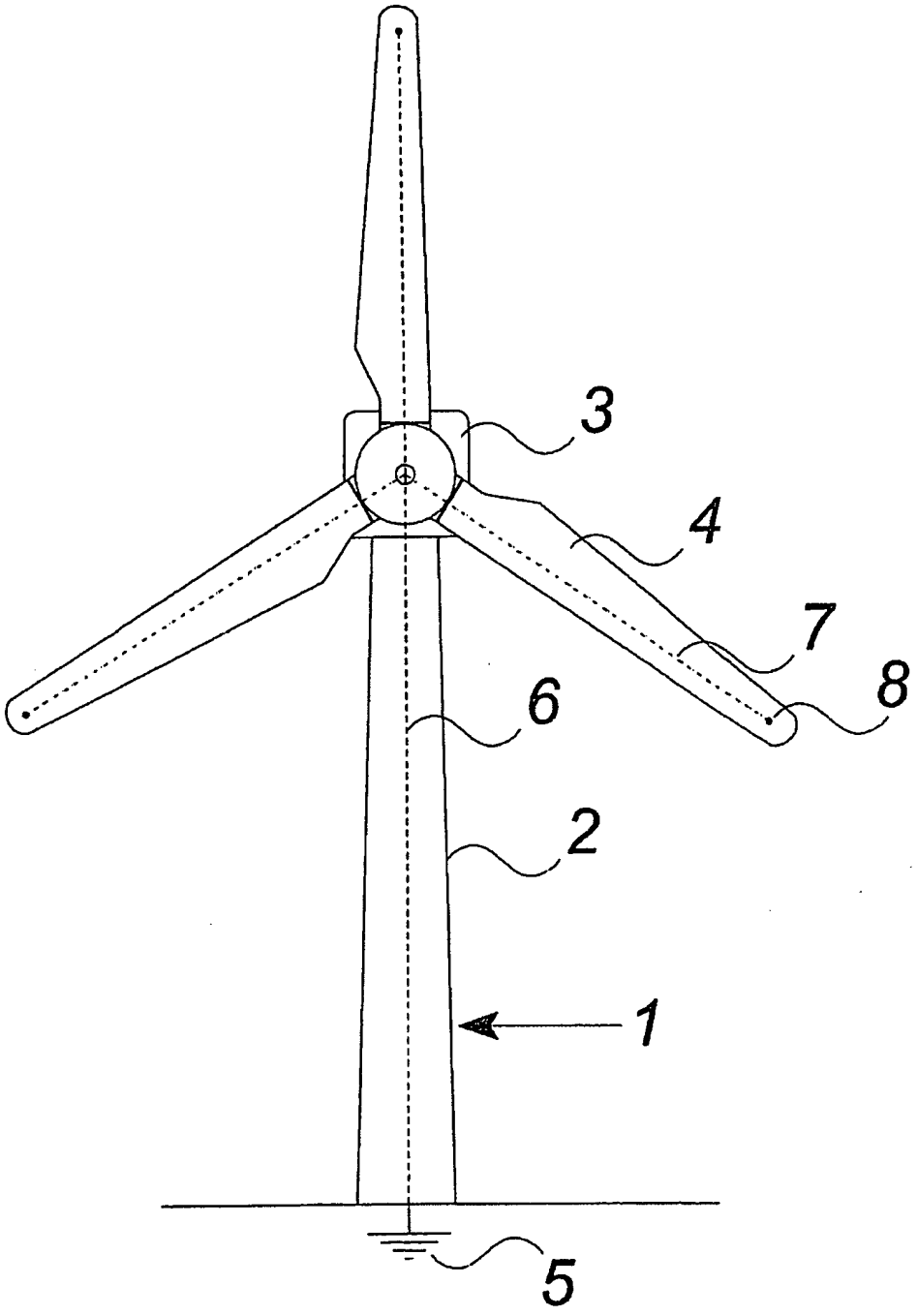

Fig. 1

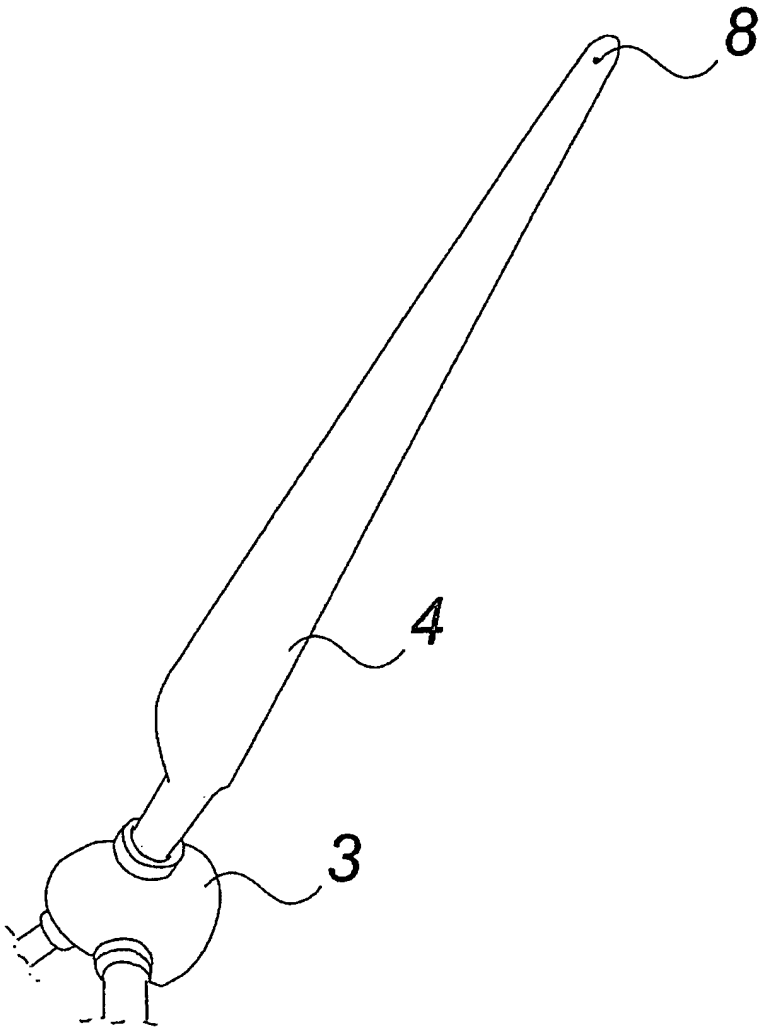

Fig. 2

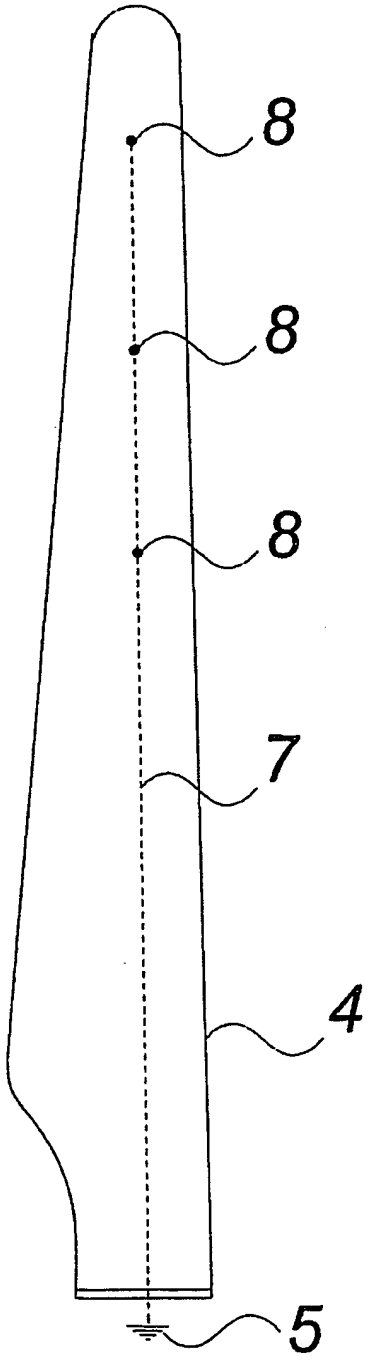

Fig. 3

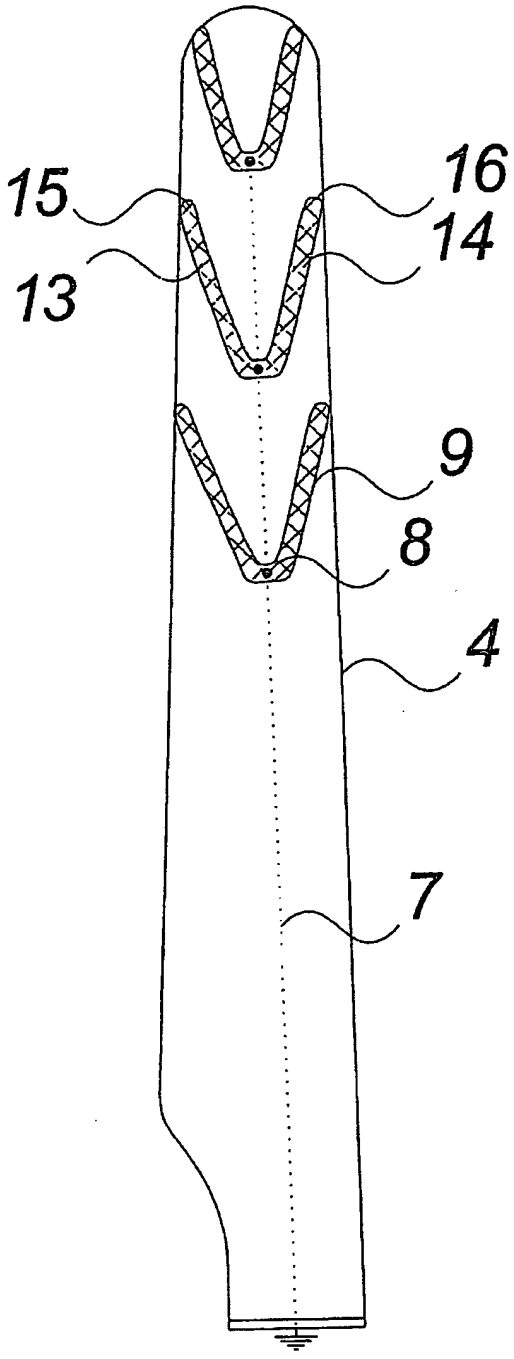

Fig. 4

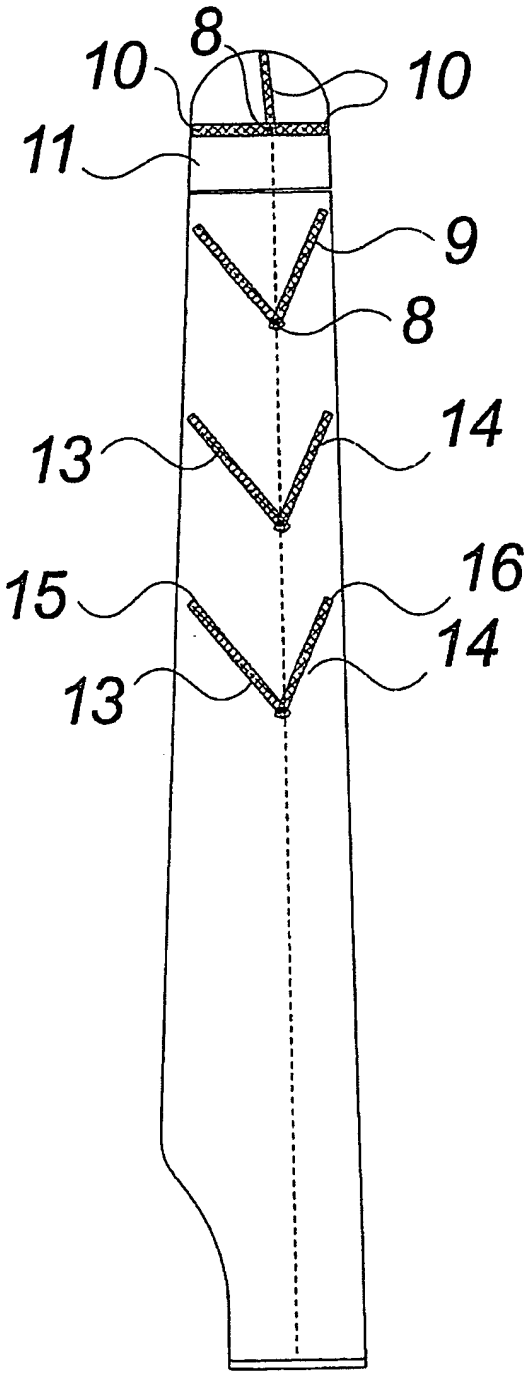

Fig. 5

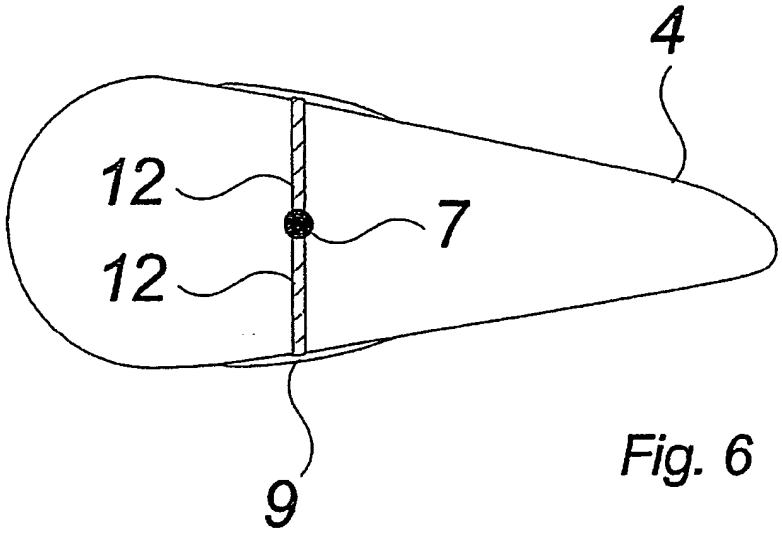

Fig. 6

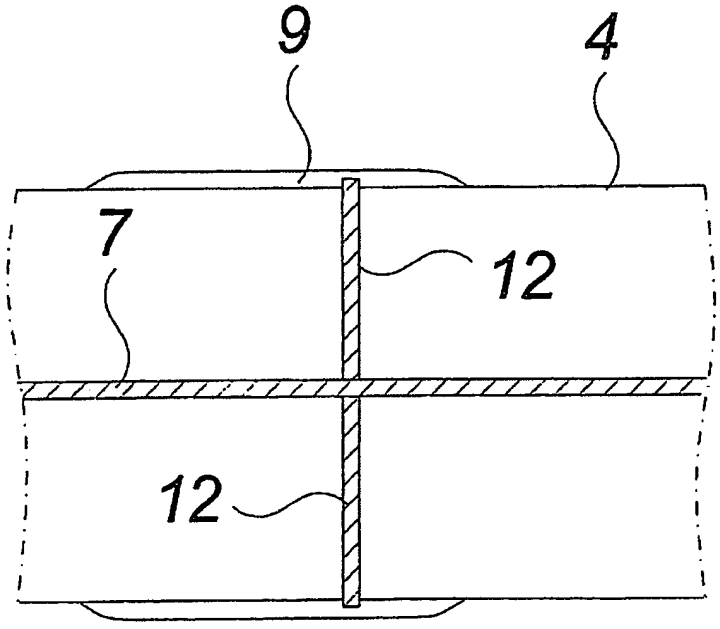

Fig. 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/DK 01/00244

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: F03D 11/00, H02G 13/00 // H05F 3/02
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: F03D, B64C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 0014405 A1 (LM GLASFIBER A/S), 16 March 2000 (16.03.00), page 3, line 14 - line 22, figures 1-2, abstract	1-5,8-12,14, 15,18,21
A	WO 9607825 A1 (BONUS ENERGY A/S), 14 March 1996 (14.03.96)	1-22

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
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Date of the actual completion of the international search	Date of mailing of the international search report
5 July 2001	-3. 08. 2001
Name and mailing address of the International Searching Authority European Patent Office P.B. 5818 Patentlaan 2 NL-2280 HV Rijswijk Tel.(+31-70)340-2040, Tx 31 651 epo nl. Fax(+31-70)340-3016	Authorized officer Leif Vingård/JAn Telephone No.

Form PCT/ISA/210 (second sheet) (July 1998)

SA : 276

INTERNATIONAL SEARCH REPORT

Information on patent family members

28/05/01

International application No.
PCT/DK 01/00244

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 0014405 A1	16/03/00	AU 5504399 A	27/03/00
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		JP 9503006 T	25/03/97

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